Redo aortic grafting after treatment of aortic graft infection

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Purpose: **This study was performed to determine the indications, operative strategy, and hemodynamic benefit of redo aortic grafting procedures after earlier excision of an infected aortic graft.**

Methods: **Among 164 patients treated for aortic graft infection, 15 later underwent redo aortic grafting procedures an average of 18 months (range, 1 to 59 months) after removal of an infected aortic graft. Redo grafting procedures were performed for leg ischemia (n = 11) or infection (proven, n = 3; suspected, n = 1). The new aortic graft originated either from the distal thoracic aorta (n = 5) or from the juxtarenal aortic stump (n = 10). Follow-up averaged 56 months (range, 7 to 110 months).**

Results: **All patients survived the redo grafting procedure. In the eleven patients who had ischemic symptoms, redo grafting procedures uniformly resulted in symptomatic improvement with an increase in ankle-brachial indexes (0.78 ± 0.34 vs 0.50 ± 0.29; $p = 0.02$). A graft limb occlusion developed in two of these patients (3 and 6 months), but no limbs were amputated. In the four patients who had proven or suspected extraanatomic bypass graft infection, there was one graft limb occlusion (29 months) and one amputation (17 months). Overall, recurrent graft infection occurred in three of 15 patients and may be more frequent in patients who have a proven extraanatomic bypass graft infection (2 of 3 vs 1 of 12; $p = 0.08$). Infection accounted for two of the three graft limb occlusions and two of the three late deaths. Recurrent infection was not associated with early (<1 year) regrafting procedures, and culture results did not correlate with the microbiologic features of the primary infection.**

Conclusions: **Redo aortic grafting procedures can be performed safely and at relatively early intervals (6 to 12 months) after removal of the infected aortic graft. The procedure reliably relieves ischemic symptoms of the hemodynamically inadequate extraanatomic bypass graft. Reinfection remains a risk after redo aortic grafting procedures, particularly when treating established extraanatomic bypass graft infection. (J Vasc Surg 1996;24:328-37.)**

The traditional management of aortic graft infection requires infected graft removal and an extraanatomic bypass (EAB) grafting procedure, usually with staging.[1-9] Because of the improved patient survival rates that accompany this treatment strategy, an increasing number of patients rely on the continued function of the EAB grafts for leg perfusion. EAB grafts traditionally are less durable than in situ aortic grafts,[10-13] especially when placed under the adverse conditions that are present during the treatment of aortic graft infection. The perfused limbs are at risk because of EAB graft thrombosis, hemodynamic insufficiency, or infection.

Treatment of the failed EAB graft becomes increasingly difficult as inflow and outflow potential are limited and limb perfusion is easily compromised. Reluctance to reuse the native aorta, which offers the best inflow source for leg revascularization, is the result of extensive scarring of the retroperitoneum and the risk of placing a prosthesis in a previously infected field. Reported experience of reoperative aortic grafting procedures in survivors of aortic graft infection has offered limited guidelines for placement of these grafts back into the previously infected bed.[14-21]

The purpose of this review is to determine the

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Table I. Treatment of original aortic graft infections

Patient no.	*Type*	*Culture result*	*Graft excision, revascularization*	*Days of intravenous antibiotics*
1	PGI	Salmonella	EAB	Unknown
2	PGI	*S. epidermidis, Enterococcus*	TEA	7
3	PGI	Diphtheroids	TEA	7
4	AEF	None obtained	EAB	1
5	AEF	Bacteroids, *Streptococcus*	EAB	14
6	AEF	*E. coli*	EAB	13
7	AEF	*S. aureus*, Diphtheroids, *E. coli*	EAB	10
8	AEF	No growth	None	10
9	AEF	*P. acnes*	EAB	14
10	AEF	Unknown	EAB	Unknown
11	PGI	*P. acnes*	EAB	10
12	PGI	*S. aureus*	EAB	27
13	PGI	*S. epidermidis*	EAB	10
14	PGI	*Xanthomonas maltiphia*	EAB	14
15	PGI	*Streptococcus*	EAB	14

PGI, Prosthetic graft infection; *AEF*, aortoenteric fistula; *EAB*, extraanatomic bypass; *TEA*, thromboendarterectomy.

indications for operation, the operative strategies used, and the early and late results of redo aortic grafting procedures after previous treatment of an infected aortic graft.

PATIENTS AND METHODS

Between 1963 and 1993, 164 patients were treated at the University of California, San Francisco for aortic graft infection, including 71 procedures for aortoenteric fistulas and 93 for prosthetic graft infections. Fifteen of these patients (9%), nine men and six women, underwent redo aortic grafting procedures for leg ischemia or EAB graft infection and are the subject of this report. Patient and follow-up data were obtained by review of the hospital charts and office and referring physician records.

Indications for the original aortic graft procedure in these fifteen patients included aneurysmal disease in seven patients and occlusive disease in eight. The original grafts were bifemoral in nine patients, biiliac in five, and an aortic tube in one, most often with an end-to-end proximal anastomosis (13 of 15).

The original aortic graft infections included seven aortoenteric fistulas and eight prosthetic graft infections, occurring an average of 56 months (range, 4 to 140 months) after the initial aortic graft placement (Table I). Culture data from the original infection were available for 14 of the patients: 11 had positive results, one had a negative result, and two had indeterminate results. Treatment of each of these infections included total graft removal and a course of intravenous antibiotics for as many as 4 weeks (mode, 14 days; median, 12 days). Leg revascularization was accomplished by EAB graft implantation in 12 patients and by aortoiliac thromboendarterectomy in two; it was considered unnecessary in one patient.

Table II. Complications involving EAB (n = 12) and their treatment

Complication	*Occurrences*	*Patients*	*Procedures before redo aortic grafting*
Occlusions	6	3	5
Hemodynamic failure	8	3	8
Prosthetic infection	4	3	1
Seroma formation	1	1	0
Limb amputation	3	2	3
Total	22	9 individuals	17

In the 12 patients who had a leg revascularized with an EAB graft, a total of 22 complications occurred before redo aortic grafting procedure, including six occlusions, eight hemodynamic failures, four prosthetic graft infections, one seroma formation, and three amputations (Table II). Seventeen procedures were performed in nine of these patients to correct EAB graft failure or infection.

Indications for redo grafting procedures included ischemic symptoms in 11 patients, a proven EAB graft infection in three, and a chronic graft seroma, suspected to be infected, in one (Table III). The average age of the patients at the time of the regrafting procedure was 64 years (range, 42 to 78). The interval between the removal of the original infected aortic graft and the placement of the new aortic graft averaged 18 months (range, 1 to 59; median, 13). Two grafts (patient numbers 3 and 4) were placed within 6 months after removal of the infected graft,

Table III. Details of redo aortic grafting procedure (n = 15)

Patient no.	*Operative indications*	*Status of EAB at time of redo*	*Interval before infection and redo (mo)*	*Proximal aortic anastamosis*	*Perioperative antibiotics (days)*
Patients with ischemic symptoms					
1	Claudication*	Patent	30	Thoracic	6
2	Claudication	None	10	Infrarenal	7
3	Rest pain	None	1	Thoracic	24
4	Rest pain	Patent	6	Thoracic	3
5	Rest pain*	Occluded	10	Thoracic	7
8	Claudication	None	10	Infrarenal	7
11	Claudication*	Patent	15	Infrarenal	3
12	Claudication	Patent	10	Thoracic	7
13	Rest pain	Patent	25	Infrarenal	Unknown
14	Rest pain*	Occluded	11	Infrarenal	6
15	Claudication	Patent	15	Infrarenal	4
Patients with proven/suspected EAB infection					
6	Infection (Staph epidermidis)	Patent	35	Infrarenal	10
7	Seroma (chronic)	Patent	22	Infrarenal	5
9	Infection (Staph epidermidis)	Patent	13	Infrarenal	7
10	Infection (no growth)	Patent	59	Infrarenal	22

*Multiple EAB occlusions.

and seven of the 15 patients underwent redo aortic infection. In patients in whom the redo grafting procedure was performed for EAB graft infection, the prosthetic bypass graft was completely removed either at the time of redo surgery (two) or within several days (two).

The redo aortic graft originated from the infrarenal position in 10 patients and from the descending thoracic aorta in the remaining five (Table III). Figs. 1 and 2 illustrate the techniques that were used for creation of these proximal anastomoses. Postoperative arteriograms are demonstrated in Fig. 3. The location of the distal anastomosis was the terminal aorta in one patient, the iliac arteries in two, the femoral bifurcation in six, and a patent uninfected prosthetic segment attached to the femoral artery in six. Concomitant procedures were performed in only one patient (number 13), who underwent transaortic bilateral renal endarterectomy. At the time of the reimplantation, the retroperitoneum was either clinically uninfected, culture negative, or both. Perioperative antibiotics were administered for a median time of 7 days (range, 3 to 24).

The statistical analysis was performed with Fisher's exact test and Student's paired *t* test, where appropriate. The numeric values are reported as the mean plus or minus the standard deviation.

RESULTS

All 15 patients survived redo aortic grafting procedures and were available for long-term follow-up, which averaged 56 months (range, 7 to 110 months; median, 48 months). Table IV summarizes the results of the procedures performed in patients who had leg ischemia or EAB graft infection in terms of graft patency, late amputation, recurrent graft infection, and survival.

Perioperative complications. Two patients (numbers 5 and 6) had an intraoperative complication: an incidental enterotomy and a splenic injury requiring a splenectomy. In the perioperative period, five of the 15 patients had a total of five complications: pulmonary (2), renal (1), graft thrombectomy (1), and groin wound infection (1). All patients left the hospital with a patent graft.

Patients treated for ischemic symptoms. Eleven patients underwent redo grafting procedures for ischemic symptoms (Table IV). Each patient either had relief of preoperative rest pain or had subjective improvement of claudication symptoms. At long-term follow-up, eight of the 11 patients remained asymptomatic, whereas the rest had stable and improved claudication without rest pain. Nine of eleven grafts remained patent throughout the follow-up period. Two occlusions occurred, at 3 and 6 months after surgery. A thrombectomy was performed in one graft; it remained patent at follow-up. The other was caused by a culture-negative recurrent graft infection 7 months after the redo aortic grafting procedure. This graft had been placed 15 months after treatment of an aortoenteric fistula; the results of the culture were positive for *Propionibacterium acnes* (Table I). The treatment of the recurrent infection involved in situ regrafting and chronic antibiotic suppression, and was successful. This patient represented the only recurrent infection in this group. No revascularized

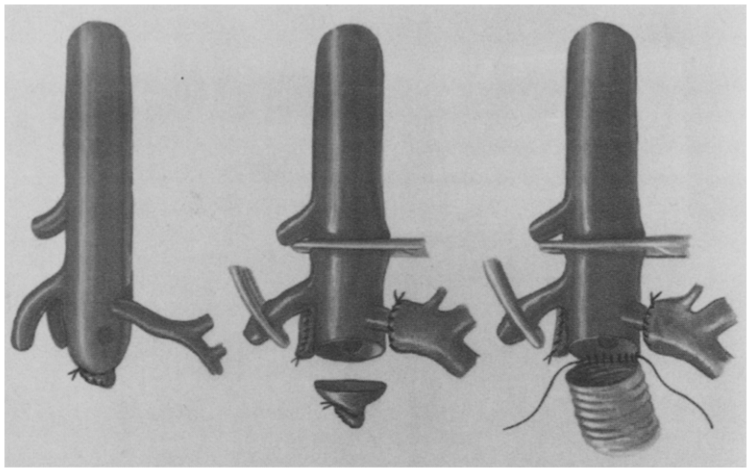

Fig. 1. Circumferential mobilization of pararenal aorta *(left)*, reopening of infrarenal stump *(middle)*, and end-to-end anastomosis with prosthetic aortic graft *(right)*. Division of left renal vein may facilitate exposure, but is not routinely performed. Reanastomosis of this vein is not necessary if adequate collateral outflow is present.

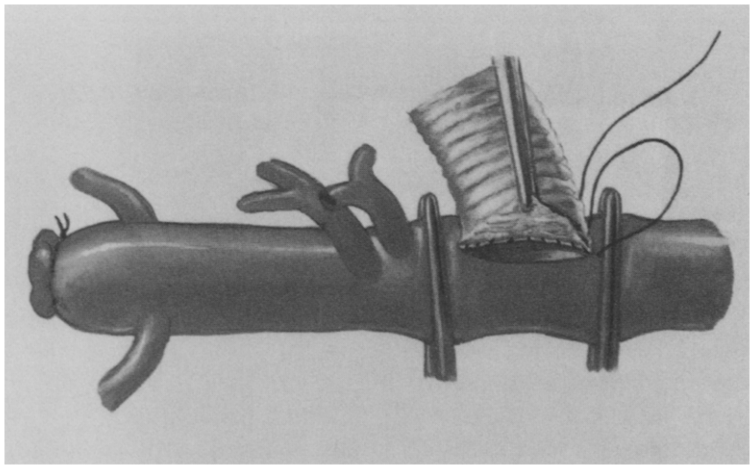

Fig. 2. Illustration of beveled end of prosthetic aortic graft attached to lateral supraceliac aortotomy.

limbs in this group were amputated during follow-up; the above-knee amputation performed in patient 3 involved a limb that was not revascularized as a result of occluded distal vessels.

Patients with EAB graft infection (proven or suspected). Four patients underwent reoperation for EAB graft infection: three proven and one suspected (seroma) (Table IV). Two of the four patients (numbers 6 and 7) have a functioning, noninfected in-line aortic graft at 41 and 81 months after the regrafting procedure. Recurrent aortic graft infection developed in the other two patients. Patient 9 was asymptomatic for 16 months after surgery until a prosthetic-colonic fistula developed. The patient's left graft limb eroded into the sigmoid colon, and she sustained a septic embolus to her left leg that necessitated an amputation shortly before her death. The original retroperitoneal infection was a *P. acnes* aortoenteric fistula (Table I). Patient 10 had a culture-negative prosthetic graft infection that occurred 29 months after the redo aortic grafting procedure. After the graft was removed and an ascending aortofemoral bypass performed, the patient survived 40 additional months, but died from sepsis. Culture results of her original graft infection are unknown. When the incidence of recurrent aortic graft infection in patients who underwent reoperation for known EAB graft infection (2/3) is compared with that in patients who underwent reoperation

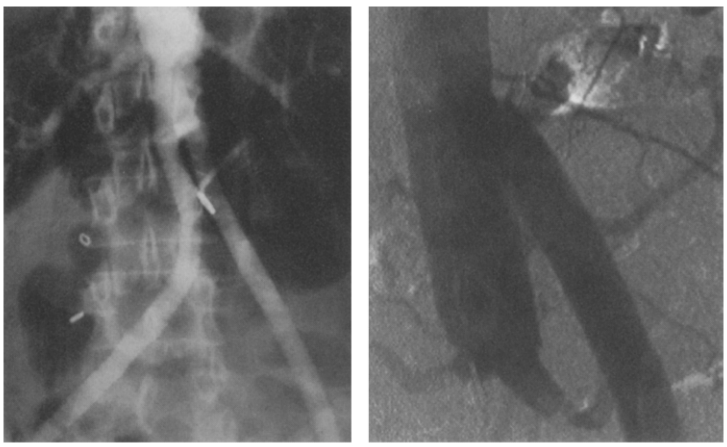

Fig. 3. Postoperative angiograms of patent redo aortic grafts originating from infrarenal stump *(left)*, and supraceliac aorta *(right)*, which takes a more lateral course.

Table IV. Long-term results of redo aortic grafting (n = 15)

Patient no.	*Redo aortic graft patency*	*Limb salvage*	*Recurrent graft infection*	*Current status*
Patients with ischemic symptoms				
1	Patent	Yes	No	Asymptomatic
2	Patent	Yes	No	Improved
3	Patent	AKA, 1 mo	No	Asymptomatic
4	Patent	Yes	No	Improved
5	Patent	Yes	No	Improved
8	Patent	Yes	No	Asymptomatic
11	Occluded, 6 mo	Yes	PGI, 7 mo	Asymptomatic
12	Patent	Yes	No	Asymptomatic
13	Patent	Yes	No	CVA, 41 mo
14	Occluded, 3 mo	Yes	No	Asymptomatic
15	Patent	Yes	No	Asymptomatic
Patients with proven/suspected EAB infection				
6	Patent	Yes	No	Asymptomatic
7	Patent	Yes	No	Asymptomatic
9	Patent	BKA, 17 mo	AEF, 16 mo	Dead, 18 mo
10	Occluded, 29 mo	Yes	PGI, 29 mo	Dead, 69 mo

AKA, Above-knee amputation; *BKA*, below-knee amputation; *PGI*, prosthetic graft infection; *AEF*, aortoenteric fistula.

without proven infection (1/12), the difference almost reaches statistical significance ($p = 0.08$, Fisher's exact test).

Hemodynamic improvement. Preoperative and postoperative ankle-arm indices were available for a total of 14 limbs (Table V). Patients who were treated for ischemia had an average preoperative ABI of 0.50 ± 0.29, which improved to 0.78 ± 0.34 ($p = 0.02$). A significant increase was also seen in patients who did not have ischemic symptoms, from 0.83 ± 0.15 to 1.06 ± 0.12 ($p = 0.002$).

Late survival. At the time of follow-up, 12 of 15 patients remained alive with a functioning graft free of infection (Table IV). Two late deaths occurred in the group treated for EAB graft infection and were caused by recurrent infection. The third death was related to a cerebrovascular accident.

DISCUSSION

Prosthetic graft infection remains one of the most devastating complications that can occur after aortic surgery. The reported treatment outcomes, however, have improved over the past decade. Before 1980, the reported mortality rate ranged from 35% to 75%, with amputation rates as high as 37% sometimes reported.[22-26] Since then, mortality rates consistently have been lower than 50%, with some larger series reporting mortality rates as low as 14%.[1-9,27] The

Table V. Summary of hemodynamic data (14 limbs)

	Ankle-arm index (average ± standard deviation)			
	Before surgery	*After surgery*	*Change*	*p*
Ischemic limbs (8)	0.53 ± 0.29	0.82 ± 0.35	0.29 ± 0.29	0.04
Nonischemic limbs (6)	0.83 ± 0.15	1.06 ± 0.12	0.23 ± 0.10	0.002
Total limbs (14)	0.67 ± 0.27	0.93 ± 0.29	0.26 ± 0.22	0.002

concomitant amputation rates, however, remain as high as 31%.[27]

With improved survival rates, more patients rely on an alternative form of leg revascularization that may not provide adequate, durable blood flow for their life span. Revascularization of the leg typically is provided by an EAB graft that originates from the axillary artery and terminates in the femoral or distal extremity arteries; contralateral limb perfusion is maintained by a femorofemoral graft. Reported patency and limb salvage rates for elective primary EAB grafts may be acceptable,[10,12] but when they are used to circumvent aortic graft infection to provide leg perfusion, they are frequently suboptimal.[1,3,5,8]

The indications for operative management of EAB graft failure in a patient with a previously treated graft infection include hemodynamic failure (thrombosis or poor graft flow) or graft infection (proven or suspected when perigraft fluid appears). Operative management can be difficult because multiple revisions may be necessary to maintain function. The primary EAB graft patency rate in patients who are treated for aortic graft infection has been reported as low as 43% at 3 years.[3] Similarly, multiple procedures may be necessary to remedy EAB graft infection, commonly reported in as many as 22% of patients.[5] Failure of the EAB graft was common among our own patients before they underwent the redo aortic grafting procedure. A total of 22 complications occurred in the 12 patients who had an EAB graft placed as part of their treatment of aortic graft infection. Nine of these patients underwent 17 operations, including three amputations, before the redo aortic grafting procedure. These figures clearly attest to the inherent difficulties of maintaining an EAB graft for the life of the patient who has had a treated graft infection.

The objective of our treatment was to reestablish inflow from the native aorta by using a standard bifurcation prosthesis. One third of the patients (5) had the graft attached to the side of the distal thoracic aorta through combined thoracoabdominal approaches (4) or transabdominal medial visceral rotation (1). The other two thirds of the patients (10) had the aortic stump reopened and the graft attached to the end of the subrenal aorta with the transabdominal (7), retroperitoneal (2), or thoracoretroperitoneal (1) approaches. Transabdominal exposures were made either with traditional infracolic approaches (5) or with left medial visceral rotation (2). The graft limbs were attached to 15 native arteries and eight residual uninfected patent prosthetic segments that were already attached to the common femoral artery.

The operative mortality rate for both approaches to the aorta in this series was zero. The distal thoracic aorta has been used as a site from which to originate an aortic graft for redo reconstructions with a low mortality rate, but experience in patients who have had previous aortic graft infection is limited.[14-18,21,28] This exposure allows the physician to avoid performing the operation in a potentially scarred field and uses a segment of aorta that is rarely involved with occlusive disease, but may contribute to respiratory complications, as seen in one of our patients. This approach allows routing of the graft limbs away from the previously infected field, thus circumventing the problem of possible residual retroperitoneal contamination.

Grafting to the juxtarenal aortic stump in a previously infected field was successful in all 10 patients in whom it was performed. The procedure requires temporary suprarenal aortic clamping to facilitate end-to-end grafting to the juxtarenal aorta. One significant technical complication occurred in the only patient in this series who had severe pararenal atherosclerosis: a transaortic endarterectomy was necessary to establish a patent aortic stump, which led to a unilateral renal artery occlusion and required a thrombectomy after surgery. Although not enough hemodynamic data are included in this report to allow these two approaches to be compared directly, the infrarenal approach offers an in-line revascularization procedure, which in the presence of severe aortic atherosclerosis may prevent further aortic thrombosis.[29] This method of reconstruction is currently our favored approach.

A major concern of redo aortic grafting proce-

dures is the timing of the reoperation in relation to the removal of the previously infected prosthesis. In 1983, Fulenwider et al.[20] reported three patients who underwent placement of a retroperitoneal graft a minimum of 2 years after septic graft removal. He reported no reinfections, with a minimum follow-up of 1 year. In our 1984 series, Reilly et al.[19] suggested that 6 to 12 months was probably sufficient to avoid reinfection in the absence of evidence that suggests ongoing retroperitoneal sepsis. Our current, updated report supports this view. Recurrent infection has not developed in any of the seven grafts that were placed within 1 year of the original infection, and no correlation between the grafting interval and recurrent infection could be made.

Although the timing of the regrafting procedure may be important, one must consider the microbiologic features of the original infection. Of the seven grafts that were placed within 1 year of the original aortic graft infection, only one was for a proven gram-negative infection. We therefore cannot generalize that regrafting within 1 year is safe for all types of infections, but we believe that caution is necessary when planning a regrafting procedure in a patient who survived an aggressive gram-negative infection.

Three of the fifteen grafts, which were placed at 13, 15, and 59 months after treatment of aortic graft infection, did become reinfected. One reinfection was caused by late erosion of the graft limb into the distal sigmoid colon, which resulted in death at 18 months. The two other patients had culture-negative infections; one patient is well and remains taking suppressive antibiotics, and the other survived for 69 months after the redo grafting procedure. None of the reinfections appear to be directly related to the previous retroperitoneal infections by culture result, hence it is difficult to conclude that reinfection was caused by the presence of continued, subclinical retroperitoneal infection. Although the cause of infection in the patient who had the graft colonic fistula is clear, the cause of the other two infections is not. One of these patients had a culture-negative EAB graft infection, presumably caused by *Staphylococcus epidermidis,* which may have contributed to the culture-negative recurrence.

Although reinfection could not be linked to an unsterile retroperitoneum, it was noted that all three infections occurred in grafts that were placed in the juxtarenal position. Although the groups are small, the incidence of reinfection for these grafts (3 of 10) was not statistically different from that of grafts that originated from the distal thoracic aorta and were routed in the far left retroperitoneum (0 of 5; $p = 0.50$). From this experience, we cannot conclude that implantation into the previous graft bed results in an increased risk of infection, other than that graft-enteric fistula is more probable solely on the basis of graft location. Furthermore, a direct comparison between the two groups may be unfair because all four patients who had proven or suspected EAB graft infection were treated with an infrarenal graft.

The purpose of the redo aortic grafting procedure is twofold: to improve blood flow for patients who have ischemic legs or to create a durable, less-susceptible alternative conduit for those who have an EAB graft infection. The results clearly show that these redo aortic grafts did improve distal perfusion—all 11 patients who underwent redo grafting procedures for ischemic symptoms had relief or improvement of their preoperative symptoms. These results appear durable as well, as eight of the 11 remained asymptomatic at the time of long-term follow-up and the other three remained stable. Overall, three of 15 grafts occluded during follow-up; however, two were related to recurrent graft infection. A successful thrombectomy was performed in the third occlusion, which has remained patent for 14 additional months. In addition, the limb salvage rate in the 11 patients who underwent redo aortic grafting procedures for the relief of distal ischemia was excellent, with no amputation of any revascularized limbs. The only amputation in this group involved previous unreconstructible disease in a limb that was deemed unsalvageable.

The hemodynamic efficacy of these grafts was confirmed by a significant improvement in the ankle-arm indexes after surgery. Although it is not surprising that the indexes of patients who have failing (or failed) reconstructions should be improved after redo aortic grafting procedures, we found that patients without ischemic symptoms and a functioning EAB graft also had improvement in the ankle-arm indices after surgery. This improvement is caused by reestablishment of in-line, unimpeded aortic blood flow.

No data yet exist on the prophylactic use of redo aortic grafting procedures. This series showed that this procedure yielded a significant improvement in limb perfusion when compared with the original EAB graft. Therefore, in selected patients who have a potentially threatened EAB graft, prophylactic redo aortic grafting procedures may be justified despite a lack of ischemic symptoms.

CONCLUSION

The definitive treatment for 15 survivors of previous aortic graft infection involved redo grafting procedures from the native aorta for ischemic or infectious complications of EAB grafts. The redo aortic grafting procedure provided safe, durable reperfusion in the legs of our patients. For patients who underwent reoperation for ischemic symptoms, the procedure provided uniform and long-term symptom relief. For patients who had proven or suspected EAB graft infection, the redo grafting procedure provided a durable, alternative conduit for limb perfusion, although this population appeared to have a higher incidence of recurrent graft infection.

The safety of redo grafting procedures in our series and the low risk of ischemia or septic complications observed in our patients during long-term follow-up support our recommendation that this treatment be offered whenever the EAB graft fails. When infection of the EAB graft occurs, the redo aortic grafting procedure should be carefully considered, and all reasonable attempts to clear the infection should be made before replacement of the aortic graft. This strategy reestablishes the aortofemoral graft, which markedly reduces the risks of a symptomatic EAB graft and, importantly, improves the quality of the patient's subsequent life.

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DISCUSSION

Dr. G. Patrick Clagett (Dallas, Tex.). I congratulate the authors on presenting sound and clinically useful data that will aid in the management of this challenging group of patients. Their report emphasizes some of the limitations of the use of EAB grafts for this condition. Dissatisfaction with EAB grafts has led us to advocate autogenous reconstruction with the superficial femoral popliteal veins or deep veins. We are nearing 5-years of follow-up in many of these patients, and the remarkable thing about these autogenous reconstructions is their durability. Reinfection is not an issue, and the patency rate is essentially 100%. We and others, however, will need to report more complete follow-up of aortic reconstructions from deep veins, and I suspect that the staged EAB grafting procedure will continue to be the most widely used operation for this problem. Therefore, this information from the extensive experience at the University of California, San Francisco is important and is something that we all need to pay attention to.

You clearly demonstrate the safety of reoperative aortic surgery in this circumstance, especially when the descending thoracic aorta is the inflow source. It is of interest that these patients underwent many reoperations in an attempt to maintain the patency of failing EAB grafts before the definitive reoperation. Do you now have a lower threshold for undertaking aortic reoperation, and what are your current indications? How many revisions and thrombectomies of an EAB graft will you allow before recommending redo aortic surgery? In a patient with occlusive disease who has particularly poor outflow, and in whom the consequences of a failed extraanatomic reconstruction would be disastrous, would you ever recommend secondary aortobifemoral bypass before occlusion or hemodynamic failure occur?

I am also intrigued with your data that suggest an increased risk of reinfection when operating on the infrarenal aorta as opposed to the descending thoracic aorta. Do you think that this is because of the bacteria that are sequestered in these retroperitoneal tissues? If so, how long does it take for sterilization of the retroperitoneum to occur? In your presentation, you mention 6 to 12 months as being the minimal safe interval before reoperation. A few patients, however, had new aortic prostheses successfully placed at earlier times, and those three who did have recurrent aortic graft infections had a prolonged interval of greater than 1 year between removal of the first infected aortic graft and placement of a new one. Is there an optimal time? Does it depend on the organism? And what guidelines do you recommend for determining when it is safe to place a new aortic prosthesis?

Again, I commend this report to all. It contains a wealth of well-documented information from a group that has made many contributions to this area.

Dr. Paul J. DiMuzio. The first questions centered around our present indications for performing redo aortic grafting procedures under these circumstances. Our study predominantly involved symptomatic patients who had undergone multiple procedures to correct failing or infected axillofemoral bypass grafts. Given what has been an overall good outcome for these patients, I think it is reasonable to lower the threshold for reestablishing flow from the native aorta. The question then becomes whether this procedure should be performed prophylactically. Perhaps the use of this approach can be considered in patients who have fully recovered from their infection and have an asymptomatic, hemodynamically compromised bypass graft. This seems reasonable given that EAB graft failure in this setting frequently occurs suddenly and has dire consequences.

The second questions asked how early can redo grafting procedures be performed safely without a significant risk of infection. Seven of the 15 grafts were placed less than 1 year after the initial infection. To date, none of them have become reinfected. Two grafts were placed within 6 months of infection and were positioned in the retroperitoneum far to the left. In the infrarenal position, four grafts were placed between 6 and 12 months after treatment, and all had satisfactory outcomes. Timing, therefore, may not be a critical issue if the patient has fully recovered from the infection. Furthermore, given that we found no correlation between the bacteriologic features of the original graft infection and the subsequent recurrences, reinfections may in fact have sources other than the retroperitoneum. With aggressive debridement and a course of intravenous antibiotics, these infections can be cleared over a course of months, and reimplantation may be safe within this time period. I would caution, however, that the bacteriologic features of the initial infection be considered. Of the seven that were reimplanted earlier than 1 year, six were for gram-positive infections and one was for a pseudomonal infection, reimplanted at 10 months. It would be prudent to consider how aggressive the original infection was and whether a gram-negative organism was involved before considering a redo grafting procedure at an early time period.

Dr. Francis Robicsek (Charlotte, N.C.). I have a problem understanding that during the time of reoperation you go back to the same site and then dig in the quagmire of the suprarenal aorta—in the middle of scars, with the potential that infection may still be present. Why didn't you use other "ports," such as the descending or ascending thoracic aorta? To me, these are virgin areas and easily accessible. This borders on masochism.

Dr. DiMuzio. Of the 15 grafts placed, five were from the supraceliac and distal thoracic aortas. As you have noted, access to this unscarred area may be easier from a technical standpoint. Reestablishment of in-line flow from the infrarenal aorta may have some theoretic advantages over this approach—possibly improved hemodynamics, for example. Dr. Stoney has been able to perform this procedure safely, and I should note that none of the procedures in which placement of an infrarenal aortic graft was planned was abandoned for another inflow source.

Dr. Dennis F. Bandyk (Tampa, Fla.). You did not mention problems with the aortic stump as an indication for redo aortic surgery or as a factor in your operative strategy. I have encountered this situation in several patients, and I wonder what you would do with a patient in whom you are contemplating a redo aortic grafting procedure and in whom some dilatation of the aortic stump or thrombus in a region of the renal arteries is demonstrated on computed tomographic scan.

Dr. DiMuzio. On reexploration of the renal stump, thrombus is a common finding and is a result of the remodeling of the ligated aorta. At operation, this thrombus is removed. Of the 15 patients, none had significant dilation of the aortic stump. One patient, however, did have significant pararenal atherosclerosis of the pararenal aorta and underwent a transaortic endarterectomy. This approach allows the opportunity to treat such disease, unlike reestablishing flow from the supraceliac aorta.

Dr. John Mannick (Boston, Mass.). I noticed that although the procedures you have performed were remarkably successful, the mortality rate from recurrent graft infection was 20%. That is a fairly hefty mortality rate. I would like you tell us whether or not all these recurrent graft infections were in those patients in whom you placed the graft in the original bed, that is, the infrarenal end-to-end graft in the original bed, or whether you had any deaths from recurrent graft infection in those patients in whom the proximal anastomosis was placed higher up.

Dr. DiMuzio. Recurrent graft infection occurred in three of the 15 patients. Two of these patients died 18 and 69 months after the redo grafting procedure, and the third patient remains alive at long-term follow-up. Although the mortality rate from recurrent infection was approximately 13%, it should be noted that these deaths occurred late and in patients who had EAB graft infections. Clearly this group of patients is the most difficult to manage, and overall this approach has offered them some chance for cure.

All three of the reinfections occurred in grafts that were placed in the original bed, end-to-end from the infrarenal aorta. Although this suggests this graft position poses a risk for reinfection, as mentioned, our data suggest that reinfection comes from sources other than the previously infected retroperitoneum. All four patients who had proven or suspected EAB graft infection—clearly a possible source of infection—underwent the repeat graft procedure in the infrarenal position. Therefore, comparing redo graft position in terms of recurrent infection rate is not possible in this selected group of patients.

Dr. C. Steven Powell (Greenville, N.C.). I would like to relate an experience of two episodes of recurrent aortoenteric fistulas in patients who have had in-line aortic grafts placed sometime in the interval after treatment of aortic graft infection or aortoenteric fistula. I think this is a potential concern with this approach.

My second question is whether you take any special measures to isolate the graft from the duodenum and bowel when you perform these redo in-line aortic graft procedures?

Dr. DiMuzio. Recurrent aortic enteric fistulae were seen in one of our patients in whom the graft limbs were routed underneath the colon. A colonic fistula occurred and ultimately led to the patient's death. We have not seen recurrent aortoenteric fistulae involving the duodenum, and no special procedures to protect the graft, other than a standard reperitonealization, were performed.